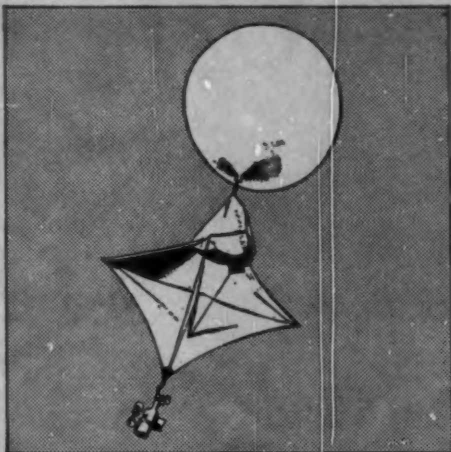
Met.O.776
METEOROLOGICAL OFFICE

the meteorological magazine

JANUARY 1966 No 1122 Vol 95
Her Majesty's Stationery Office



high performance

High performance Beritex seamless Meteorological Balloons are produced from top-grade rubber manufactured throughout under strict laboratory control. Each balloon is subjected to six separate inspection stages and every 25th balloon is tested to destruction. Beritex standards ensure top performance and reliability.

BERITEX SEAMLESS SOUNDING BALLOONS - PILOT BALLOONS CEILING BALLOONS AND HIGH ALTITUDE BALLOONS

Beritex

Hygrometric Tables

The adoption by the Meteorological Office of the recommendations relating to the formulae for saturation vapour pressures as specified in the *Technical Regulations* of the World Meteorological Organization (Vol. I, General, WMO—No. 49. BD. 2—2nd edn., Supplement No. 2, Geneva, 1963) has necessitated the preparation of new editions of *Hygrometric Tables*. The tables are published in separate parts as follows:

Part I—Met. O. 265a Fahrenheit screen values. 10s. (10s. 6d.)

Part II—Met. O. 265b Celsius screen values. 12s. 6d. (13s.)

Part III—Met. O. 265c Celsius aspirated values 12s. 6d. (13s.)

Prices in brackets include postage

Published by

HER MAJESTY'S STATIONERY OFFICE

and obtainable from the Government Bookshops in London (post orders to P O Box 569, S.E.1.), Edinburgh, Cardiff, Belfast, Manchester, Birmingham and Bristol or through any bookseller

METEOROLOGICAL OFFICE Met.O.776

THE METEOROLOGICAL MAGAZINE

Vol. 95, No. 1122, January 1966

551.509.324.2:551.509.54:551.524.77 (423+429)

THE FORECASTING OF SHOWER ACTIVITY IN AIRSTREAMS FROM THE NORTH-WEST QUARTER OVER SOUTH-WEST ENGLAND AND SOUTH WALES IN SUMMERTIME

By C. A. S. LOWNDES

Introduction.—In an earlier paper[1] a study was made of the shower activity in airstreams from the north-west quarter over south-east England in summertime and the relative usefulness of a number of predictors for forecasting shower activity, thunder and hail was evaluated. The present work deals in the same way with the problem of forecasting shower activity over south-west England and south Wales in summertime. The investigation was again restricted to airstreams which approached the British Isles from the north-west quarter. This was achieved by including only those days when the surface isobars over south-west England and south Wales at midday showed a flow from between west and north-west inclusive and the polar front lay to the south of the British Isles or had cleared south-west England by 0600 GMT. Occasions were not included if a front was situated over south-west England or south Wales between 0900 and 2100 GMT or if the precipitation was not mainly showery. The classification of the intensity of shower activity was based on reports from eight stations in the months May to September during the 10-year period from 1954 to 1963. From 1956, the stations were Ross-on-Wye, Bristol, Aberporth, Plymouth, Chivenor, St. Mawgan, Culdrose and Scilly. Before 1956, St. Eval was used instead of St. Mawgan. From the Beaufort letters in the *Daily Weather Report** the total number of mentions of slight, moderate and heavy showers at the eight stations during the period 0900 to 2100 GMT was obtained for each day. From these figures, the intensity of shower activity was classified as follows :

- *A* Widespread showers with a good proportion of moderate or heavy showers (8 or more mentions of showers ; more than 25 per cent moderate or heavy showers).
- *B* Widespread showers with few moderate or heavy showers (8 or more mentions of showers ; 25 per cent or less of moderate or heavy showers).
- *C* Few showers (Less than 8 mentions of showers).
- *D* No showers.

* London, Meteorological Office. Daily Weather Report. London, HMSO.

A note was made of thunder or hail reported between 0900 and 2100 GMT at any station in south-west England or south Wales included in the *Daily Weather Report*. Surface reports were supplemented by sferic (atmospherics) observations during the same hours of the day.

The factors which were considered.—It is reasonable to associate the degree of shower activity primarily with the degree of instability of the lower troposphere as indicated by the dry-bulb temperatures. Instability can be assessed in a simple fashion in various ways, of which seven were chosen for this investigation*, (1) the 1000–500 mb thickness anomaly, (2) the 1000–700 mb thickness anomaly, (3) the 700 mb temperature anomaly, (4) the Boyden instability index,[2] (5) the Rackliff instability index,[3] (6) the Jefferson instability index[4] and (7) the modified Jefferson instability index.[5]

The thickness anomalies are departures from a climatological normal of thickness values and are closely related to the general excess or deficiency of air temperature which in turn is related to the degree of instability resulting from surface heating. The anomaly of 700 mb temperature is a fair measure of the instability attainable between the ground and the freezing-level. The instability indices, which were all devised for thunderstorm forecasting, are measures of instability which dispense with climatic normals. Apart from the humidity measurements inherent in the Rackliff and Jefferson indices, humidities in the troposphere were not considered because the variations in space and with time are large and difficult to forecast and because a high relative humidity may be simply the consequence of the evaporation of raindrops from a shower and may not be representative of the airmass. However, it became clear that the level of surface pressure was a useful predictor in association with the thickness and temperature anomalies, probably because of the well-known association between high surface pressure and relatively dry air aloft.

Other factors considered included the position of the associated depression and the curvature of the surface isobars over south-west England and south Wales.

Association with surface synoptic features.—

The position of the associated depression at midday.—Table I shows for each class of shower activity the number of occasions when the depression with which the polar air was associated was situated in a particular locality.

On 82 per cent of occasions when the depression was situated over Scotland there were widespread showers over south-west England and south Wales (classes *A* and *B*). On 71 per cent of occasions when the depression was situated over the Norwegian Sea or the Arctic there were few showers or no showers (classes *C* and *D*). In general, the nearer the depression was to the British Isles, the more intense was the shower activity in south-west England and south Wales. This suggests that the isobaric curvature and the level of surface pressure over the British Isles might be useful predictors.

The curvature of the surface isobars.—On many days of widespread showers, a surface trough moved eastwards or southwards across south-west England. Of

* For the years 1954 and 1955, solar radiation and lag corrections have been applied to the upper air temperatures and thicknesses to make them comparable with the data for 1956 to 1963 to which the corrections had already been applied.

TABLE I—SHOWER ACTIVITY RELATED TO POSITION OF ASSOCIATED DEPRESSION AT MIDDAY (MAY–SEPTEMBER 1954–63)

Position of depression	Class of shower activity *A*	*B*	*C*	*D*
	Number of occasions			
Arctic	0	0	2	0
Iceland region	1	1	3	1
Norwegian Sea	4	2	10	3
Scandinavia	11	2	17	6
North of Scotland	7	5	8	2
West of Scotland	1	1	0	0
Scotland	12	2	3	0
North Sea	16	8	11	2
Irish Sea	2	0	0	0
England	1	0	1	0
Denmark	0	1	6	1
Germany	0	0	1	0
All areas	55	22	62	15

the troughs which moved eastwards, 50 per cent were major features with the trough axis some 600 to 1000 miles in length and 50 per cent were minor perturbations with the trough axis some 200 to 600 miles in length. Of the troughs which moved southwards, 20 per cent were major features and 80 per cent were minor perturbations. Table II shows the number of these occasions for each class of shower activity.

TABLE II—SHOWER ACTIVITY RELATED TO THE CURVATURE OF THE SURFACE ISOBARS OVER SOUTH-WEST ENGLAND (MAY–SEPTEMBER 1954–63)

	Class of shower activity *A*	*B*	*C*	*D*
	Number of occasions			
Surface trough moved eastwards across south-west England	22	2	3	0
Surface trough moved southwards across south-west England	10	1	2	0
Uniform cyclonic isobars over south-west England	11	6	3	0
Neither surface trough nor cyclonic isobars	12	13	54	15
Total	55	22	62	15

On 58 per cent of occasions of widespread showers with a good proportion of moderate or heavy showers (class *A*) a surface trough moved eastwards or southwards across south-west England. Of the 15 days on which a major surface trough moved across south-west England, 13 (87 per cent) were associated with widespread showers with a good proportion of moderate or heavy showers and 7 (47 per cent) with thunder. Of the 25 days on which a minor perturbation moved across south-west England, 19 (76 per cent) were associated with widespread showers with a good proportion of moderate or heavy showers and 13 (52 per cent) with thunder. Of the 20 days with uniform cyclonic isobars over south-west England, 17 (85 per cent) were associated with widespread showers (classes *A* and *B*) and 8 (40 per cent) with thunder. There were no occasions of widespread showers when the isobars over south-west England were anticyclonic. On 90 per cent of occasions of few showers or no showers (classes *C* and *D*) there were neither surface troughs nor uniform cyclonic isobars. On 29 per cent of occasions of few showers or no showers, the isobars over south-west England were anticyclonic.

Association with 700 mb temperature and surface pressure.—The following data were extracted :

(i) The 700 mb temperature anomaly at Camborne for 1200 GMT (1500 GMT before 1957). The anomaly was based on the 5-day mean temperatures given in Table III.

(ii) The mean sea level pressure at Chivenor for 1200 GMT.

TABLE III—5-DAY MEAN 700 MB TEMPERATURE AT CAMBORNE* IN °C

Period	Mean	Period	Mean	Period	Mean
1–5 May	−5	30 June– 4 July	0	29 Aug– 2 Sept	0
6–10	−5	5– 9 July	0	3– 7	0
11–15	−5	10–14	+1	8–12	0
16–20	−4	15–19	+1	13–17	−1
21–25	−4	20–24	+1	18–22	−1
26–30	−3	25–29	+1	23–27	−1
				28 Sept– 2 Oct	−1
31 May– 4 June	−3	30 July– 3 Aug	+1		
5– 9 June	−2	4– 8 Aug	+1		
10–14	−2	9–13	+1		
15–19	−1	14–18	+1		
20–24	−1	19–23	+1		
25–29	0	24–28	0		

*Obtained from 5-year monthly means for the period 1951–55. The monthly mean values were based on midday and midnight ascents and were corrected for radiation and lag errors.

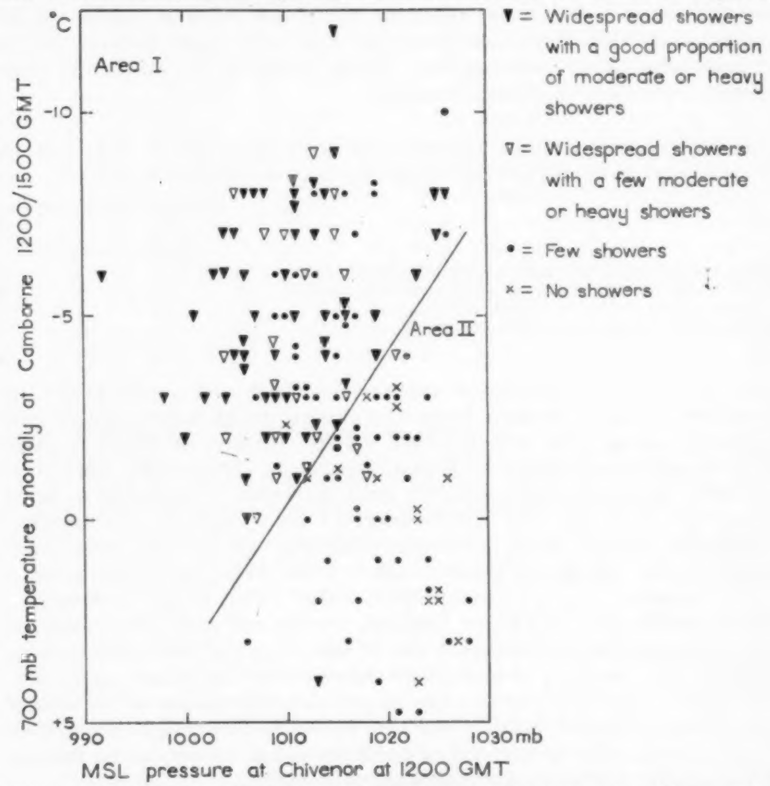


FIGURE 1—SHOWER ACTIVITY IN SOUTH-WEST ENGLAND AND SOUTH WALES ASSOCIATED WITH SURFACE PRESSURE AND THE 700 MB TEMPERATURE ANOMALY

The line divides the diagram into area I containing most of the occasions of widespread showers and area II containing most of the occasions of few or no showers.

Rain showers.—A diagram was plotted (Figure 1) of the 700 mb temperature anomaly at Camborne against the mean sea level pressure at Chivenor. The various intensities of shower activity are indicated by symbols, class *A* by a black triangle, class *B* by an open triangle, class *C* by a dot and class *D* by a cross. The diagram can be divided into two areas as indicated. If the diagram were used to forecast either widespread showers or few showers/no showers, a 'skill score' of 0·62 would be obtained. The skill score S^6 is defined by

$$S = \frac{\text{number of correct forecasts} - \text{number correct by chance}}{\text{total number of forecasts} - \text{number correct by chance}}$$

It ranges from 0 for no success to 1 for complete accuracy.

Rainfall amount.—A similar diagram (Figure 2) was plotted, the symbols representing the average rainfall between 0900 and 2100 GMT for the eight

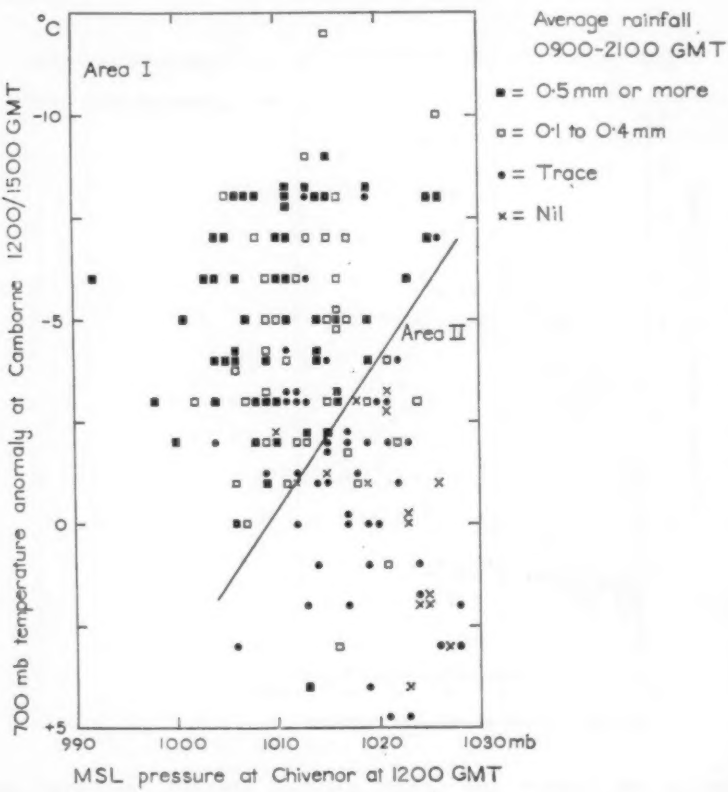


FIGURE 2—AVERAGE RAINFALL FOR EIGHT STATIONS IN SOUTH-WEST ENGLAND AND SOUTH WALES FOR EACH INDIVIDUAL DAY ASSOCIATED WITH SURFACE PRESSURE AND THE 700 MB TEMPERATURE ANOMALY

Areas I and II are the same areas as in Figure 1.

stations in south-west England and south Wales for each day examined. The diagram can be divided into the same two areas which were used in Figure 1. If the diagram were used to indicate an average rainfall of either 0·1 mm or more, or less than 0·1 mm, a skill score of 0·67 would be obtained.

If it were used to indicate an average rainfall of either 0·5 mm or more, or less than 0·5 mm, a skill score of 0·44 would be obtained.

Figure 3 shows the highest and lowest rainfall amounts plotted against the average amount for the eight stations in south-west England and south Wales for each day examined. For an average value of up to 0·5 mm, the highest value is likely to be about five times the average and for an average value of more than 0·5 mm, about four times the average. For an average value of up to 1 mm, the lowest value was nil or a trace and for an average value above 1 mm the lowest value varied between nil and 2 mm. It is clear

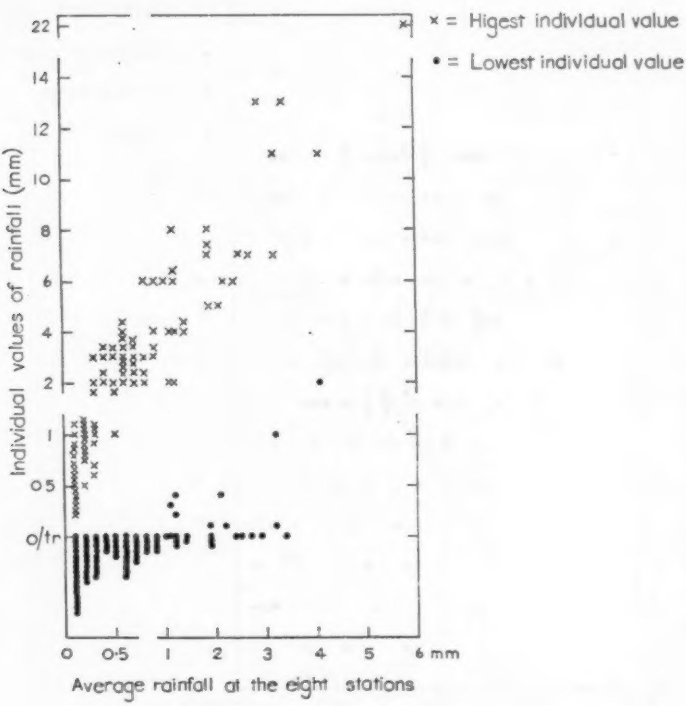


FIGURE 3—THE HIGHEST AND LOWEST RAINFALL AMOUNTS (0900–2100 GMT) ASSOCIATED WITH AVERAGE VALUES FOR EIGHT STATIONS IN SOUTH-WEST ENGLAND AND SOUTH WALES

For some values of the average rainfall the lowest amount was zero on several occasions and such occasions are plotted below the axis.

that however widespread the showers, some places are likely to escape with little or no rain.

Thunder and hail.—A diagram was plotted (Figure 4) of the 700 mb temperature anomaly against mean sea level pressure with symbols representing thunder or hail. If no thunder or hail was reported, a cross was plotted. The diagram can be divided into two areas as indicated. If the diagram were used to indicate thunder or no thunder, a skill score of 0·31 would be obtained.

For an indication of hail or no hail, a skill score of 0·15 would be obtained.

On all but one occasion of thunder and on all occasions of hail, the negative temperature anomaly was 2 deg C or more.

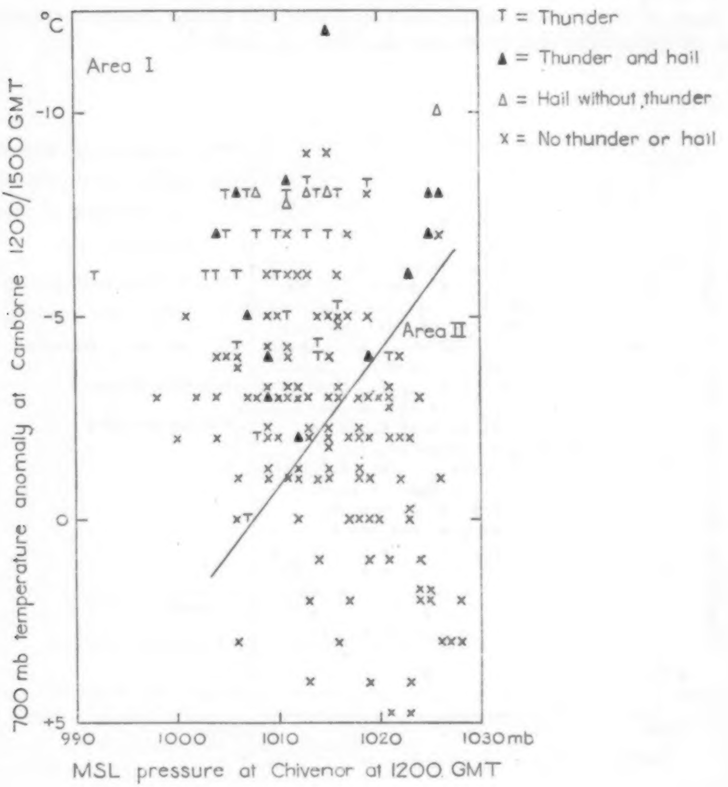


FIGURE 4—THUNDER AND HAIL IN SOUTH-WEST ENGLAND AND SOUTH WALES ASSOCIATED WITH SURFACE PRESSURE AND THE 700 MB TEMPERATURE ANOMALY

Sunshine.—A study of the average duration of sunshine for the eight stations in south-west England and south Wales for each day examined revealed no evidence of any association between the intensity of shower activity and the duration of sunshine.

Association with 1000–500 mb thickness and surface pressure.—The 1000–500 mb thickness anomaly at Camborne for 1200 GMT (1500 GMT before 1957) was extracted. Anomalies were measured from 5-day mean thickness values for Camborne given in Table IV.

An analysis was carried out with the 1000–500 mb thickness anomaly in place of the 700 mb temperature anomaly and statistics were extracted to construct Figures 5, 6 and 7. The corresponding skill scores are shown in Table V.

An analysis was also carried out with the 1000–700 mb thickness anomaly in place of the 700 mb temperature anomaly and similar statistics extracted. The corresponding skill scores are also shown in Table V.

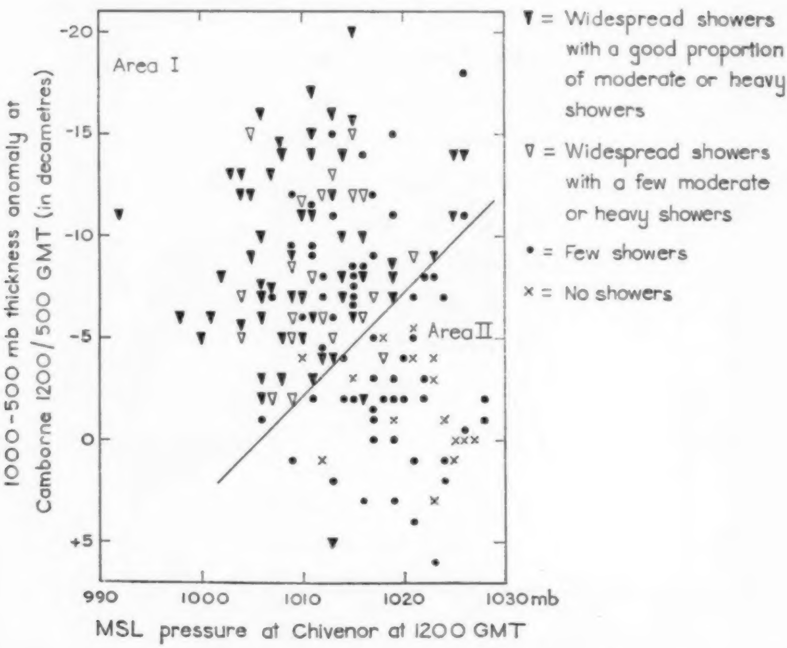


FIGURE 5—SHOWER ACTIVITY IN SOUTH-WEST ENGLAND AND SOUTH WALES ASSOCIATED WITH SURFACE PRESSURE AND THE 1000–500 MB THICKNESS ANOMALY

The line divides the diagram into area I containing most of the occasions of widespread showers and area II containing most of the occasions of few or no showers.

TABLE IV—5-DAY MEAN 1000–500 MB THICKNESS AT CAMBORNE* IN DECAMETRES

Period	Mean	Period	Mean	Period	Mean
1– 5 May	544	30 June– 4 July	555	29 Aug– 2 Sept	555
6–10	544	5– 9 July	556	3– 7 Sept	555
11–15	545	10–14	557	8–12	554
16–20	546	15–19	557	13–17	554
21–25	547	20–24	557	18–22	553
26–30	548	25–29	557	23–27	553
				28 Sept– 2 Oct	552
31 May– 4 June	549	30 July– 3 Aug	557		
5– 9 June	550	4– 8 Aug	556		
10–14	551	9–13	556		
15–19	552	14–18	556		
20–24	553	19–23	556		
25–29	554	24–28	555		

*Obtained from 5-year monthly means for the period 1951–55. The monthly mean values were based on midday and midnight ascents and were corrected for radiation and lag errors.

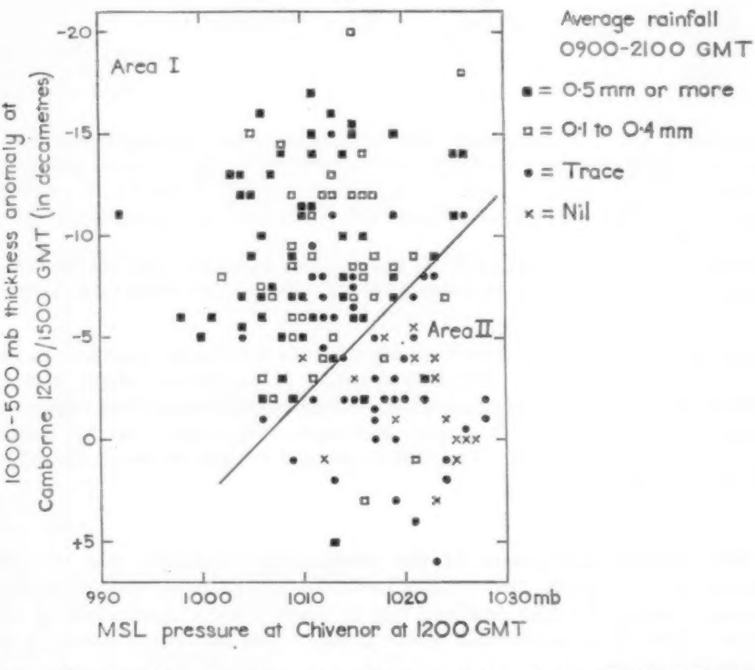


FIGURE 6—AVERAGE RAINFALL FOR EIGHT STATIONS IN SOUTH-WEST ENGLAND AND SOUTH WALES FOR EACH INDIVIDUAL DAY ASSOCIATED WITH SURFACE PRESSURE AND THE 1000–500 MB THICKNESS ANOMALY

Areas I and II are the same areas as in Figure 5.

Association with the instability indices.—The Boyden instability index,[2] the Rackliff instability index,[3] the Jefferson instability index[4] and the

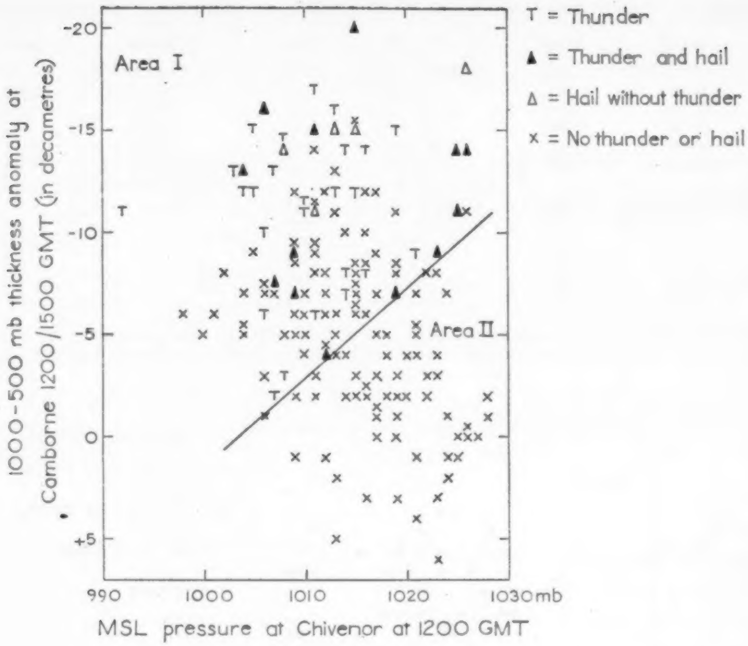


FIGURE 7—THUNDER AND HAIL IN SOUTH-WEST ENGLAND AND SOUTH WALES ASSOCIATED WITH SURFACE PRESSURE AND THE 1000–500 MB THICKNESS ANOMALY

modified Jefferson index[5] were calculated for the Camborne 1200 GMT ascents (1500 GMT before 1957). The critical values of the indices which gave the highest skill scores in forecasting either widespread showers or few showers/no showers were obtained. A similar procedure was carried out for rainfall amount, thunder and hail. The skill scores and critical values of the indices are given in Table V.

The relative usefulness of the predictors.—Assuming that the predictors can be forecast, their relative usefulness in forecasting shower activity, rainfall amount, thunder and hail can be assessed by a comparison of skill scores. Table V shows the skill scores obtained and the critical values of the instability indices.

The highest scores for the forecasting of shower activity and the lower rainfall amounts are obtained by the 700 mb temperature and the 1000–500 mb thickness predictors. The 1000–700 mb thickness predictor is rather less successful than the 1000–500 mb thickness predictor. The highest scores for the forecasting of the higher rainfall amounts and thunder are obtained by the Boyden instability index. None of the predictors provide a useful indication of the likelihood of hail.

TABLE V—A COMPARISON OF SKILL SCORES

Predictors	Shower activity	Rainfall (limit 0·1 mm)	Rainfall (limit 0·5 mm)	Thunder	Hail
700 mb temperature anomaly and surface pressure	0·62	0·67	0·44	0·31	0·15
1000–500 mb thickness anomaly and surface pressure	0·59	0·67	0·37	0·31	0·14
1000–700 mb thickness anomaly and surface pressure	0·52	0·57	0·33	0·25	0·10
Boyden instability index (critical values)	0·36 (93/94)	0·46 (91/92)	0·50 (93/94)	0·50 (94/95)	0·21 (94/95)
Rackliff instability index (critical values)	0·39 (25/26)	0·48 (25/26)	0·34 (30/31)	0·40 (31/32)	0·15 (31/32)
Jefferson instability index (critical values)	0·46 (21/22)	0·52 (21/22)	0·44 (22/23)	0·45 (24/25)	0·04 (24/25)
Modified Jefferson instability index (critical values)	0·43 (17/18)	0·54 (17/18)	0·47 (21/22)	0·43 (24/25)	0·06 (24/25)

The geographical distribution of the showers.—Of the 8 stations used in the analysis, half are situated on the windward coast, that is, Aberporth, Chivenor, St. Mawgan (St. Eval) and Scilly, whilst Culdrose is not far from the windward coast (see Figure 8). One would expect a rather narrow coastal

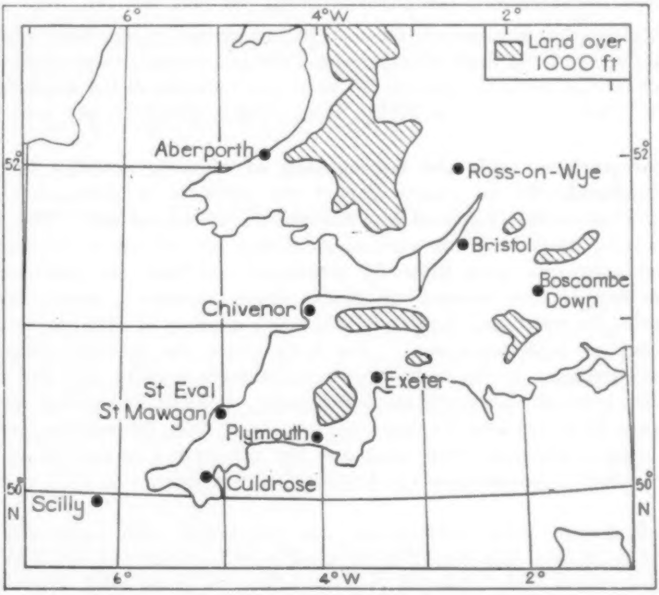


FIGURE 8—THE POSITIONS OF THE STATIONS USED

strip in which showers would be absent or weak on days when showers would not be initiated at sea and these stations might not be representative of south-west England as a whole. An indication of the variation of shower activity over the area was obtained by an analysis of the rainfall at each of the 8 stations and also at Exeter and Boscombe Down, stations some distance from the windward coast.

TABLE VI—RAINFALL FROM SHOWERS AT EACH INDIVIDUAL STATION (MAY – SEPTEMBER 1954–63)

Station	Average rainfall (mm)	Percentage of days with 0·5 mm or more	Percentage of days with nil or trace
Boscombe Down	1·0	34	54
Ross-on-Wye	0·9	27	60
Bristol	0·9	28	62
Exeter	0·7	27	60
Plymouth	0·5	23	61
Aberporth	0·5	21	71
Chivenor	0·4	21	67
St. Mawgan (St. Eval)	0·4	19	67
Culdrose	0·3	18	77
Scilly	0·2	16	71

Table VI shows that the stations on or near the windward coast had the lowest average rainfall from showers ranging from 0·2 mm at Scilly to 0·5 mm at Aberporth. The average rainfall at the other stations ranged from 0·5 mm at Plymouth to 1·0 mm at Boscombe Down. The windward coast stations also had the lowest percentage of days with a total rainfall of 0·5 mm or more, averaging 19 per cent compared with 28 per cent for the other stations. The percentage of days with nil or a trace of rain averaged 71 per cent for the windward coast stations compared with 59 per cent for the other stations.

It is clear that stations on or near the windward coasts have rather less rainfall from showers than inland stations, the percentage of days with 0·5 mm or more of rain being on average about 10 per cent less at the coastal stations and the percentage of days with a trace or less about 10 per cent higher.

A comparison with the forecasting of shower activity in south-east England.—In an earlier paper[1] the problem of forecasting shower activity in south-east England was examined in a similar way. The forecast skill scores obtained by the various predictors are all lower for south-west England compared with those for south-east England. In particular, the 700 mb temperature anomaly predictor which provides a useful indication of thunder for south-east England (skill score 0·62) is of little use for south-west England (skill score 0·31). For both areas, the 700 mb temperature anomaly predictor is the best indicator of shower activity and the Boyden instability index the best indicator of thunder. It seems likely that the lower skill scores for south-west England are associated with the relative proximity of this area to the windward coast and the consequent motion of air across the area which is less subjected to heating from the land.

Conclusions.—This investigation was concerned with polar airstreams from the north-west quarter affecting south-west England and south Wales in summertime and was restricted to days when no fronts were situated over this area. Widespread showers are likely if the associated depression is

situated over Scotland, west of Scotland or over the Irish Sea at midday. Few showers are likely if the depression is situated over the Norwegian Sea or the Arctic. Widespread showers with a good proportion of moderate or heavy showers are likely if a major surface trough or minor perturbation moves across south-west England with thunder likely to occur on about half the occasions. Widespread showers are also likely on days with uniform cyclonic isobars over south-west England. Few showers or no showers are likely if the isobars are anticyclonic.

Places on or near the windward coasts have rather less rainfall from showers than inland stations, the percentage of days with a trace or less of precipitation being about 10 per cent higher at windward coast stations.

The best indication of the intensity of shower activity can be obtained from (1) the 700 mb temperature anomaly at Camborne and the surface pressure at Chivenor and (2) the 1000–500 mb thickness anomaly at Camborne and the surface pressure at Chivenor. The Boyden instability index gives the best indication of the likelihood of thunder. None of the predictors provides a useful indication of the likelihood of hail.

The relative usefulness of the predictors has been evaluated ; which is to be preferred in forecasting depends largely on how successfully each can be forecast.

REFERENCES

1. LOWNDES, C. A. S. ; The forecasting of shower activity in airstreams from the north-west quarter over south-east England in summertime. *Met. Mag., London*, **94**, 1965, p. 264.
2. BOYDEN, C. J. ; A simple instability index for use as a synoptic parameter. *Met. Mag., London*, **92**, 1963, p. 198.
3. RACKLIFF, P. G. ; Application of an instability index to regional forecasting. *Met. Mag., London*, **91**, 1962, p. 113
4. JEFFERSON, G. J. ; A modified instability index. *Met. Mag., London*, **92**, 1963, p. 92.
5. JEFFERSON, G. J. ; A further development of the instability index. *Met. Mag., London*, **92**, 1963, p. 313.
6. JOHNSON, D. H. ; Forecast verification : a critical survey of the literature. (Unpublished, copy available in Meteorological Office Library.)

551.524.37 (426):551.584.2

LOW MINIMUM TEMPERATURES AT SANTON DOWNHAM, NORFOLK

By J. OLIVER

University College, Swansea

Local climatic contrasts occasionally reveal extremes which are more striking than regional differences. These local characteristics are most often associated with topographical conditions. Human modification of the surface or of the lower part of the atmosphere may also have a significant effect. Some of the most marked local meteorological features are experienced in frost hollows. An interesting example of the development of low temperature minima due to local factors is provided by the record available for Santon Downham from 1958.

Although the record is a short one, it is sufficient to place Santon Downham amongst those stations, below 1000 feet above MSL, which have a high frequency of air and ground frosts and low night temperature minima. The data tabulated in Table I (*a*), (*b*) and (*c*) show that, out of over 300 stations below

1000 feet listed in the *Monthly Weather Report** (see Table II), Santon Downham quite frequently records the lowest monthly extreme.

TABLE I—FROSTS AND EXTREME MINIMUM TEMPERATURES AT SANTON DOWNHAM, NORFOLK, DURING 1958–64

(*a*) Number of stations, below 1000 feet, in England, Wales and Northern Ireland with more air frosts than Santon Downham.

1958	1959	1960	1961	1962	1963	1964
4	2	3	2	1	0	1

(*b*) Number of stations, below 1000 feet, in England, Wales and Northern Ireland with more grass minimum temperatures below 0·0°C (–0·9°C or below for 1960 and earlier) than Santon Downham.

1958	1959	1960	1961	1962	1963	1964
4	0	1	1	1	1	2

(*c*) Number of stations, below 1000 feet, in England, Wales and Northern Ireland with lower extreme minimum temperatures than Santon Downham in June, July and August.

	1958	1959	1960	1961	1962	1963	1964
June	0	0	0	0	0	17	4
July	4	0	0	0	0	0	1
August	0	2	0	2	0	4	1

TABLE II—NUMBER OF STATIONS, EXCLUDING THOSE IN SCOTLAND, BELOW 1000 FEET REPORTING MINIMUM TEMPERATURES IN THE MONTHLY WEATHER REPORT

1958	1959	1960	1961	1962	1963	1964
316	327	332	333	344	348	363

The meteorological station at Santon Downham is located about one mile north of the Valley of the Little Ouse at Grime's Graves (National Grid Reference 813901), 80 feet above MSL, in the Breckland of west Norfolk (see Figure 1). The site is on a small shelf on a gentle slope with a southerly aspect and in a clearing in the 52,000-acre Thetford Forest. The vegetation of the clearing is short grass-heath, whilst the nearest trees are some 150 feet away towards the west. The light sandy soils, which characterize much of the Breckland, are free-draining and dry out readily, particularly since the mean annual rainfall of the area is only about 24 inches. The station is located sufficiently far away from the coast, being 26 miles from the Wash and 45 miles from the nearest eastern coast, for the ameliorating effects of the sea on nocturnal or winter temperatures to be significantly limited. Diurnal variations of temperature are considerable in this area.

The comparison between Santon Downham and other British stations (excluding Scotland) for the period 1958–64 is interesting. Although at Santon Downham January is the month with the greatest incidence of frost on average, a particular feature of the site is that there are low night minima in the period June to August. There is, in fact, no month in the year when frost has not been recorded at Santon Downham. Table I (*c*) shows that few other stations have recorded lower monthly extreme minima in June, July and August. Where other stations have been colder they have not been consistently the same ones so that Santon Downham is the coldest station on the greatest number of occasions compared with any other single station. The station has recorded the lowest known June temperature in Britain of –5·6°C.[1] This was on 1 June 1962 when the next coldest station was Lincoln with –4·4°C.[1] June, in general, is a month in which, in the Breckland, frosts can

*London, Meteorological Office. Monthly Weather Report. London, HMSO

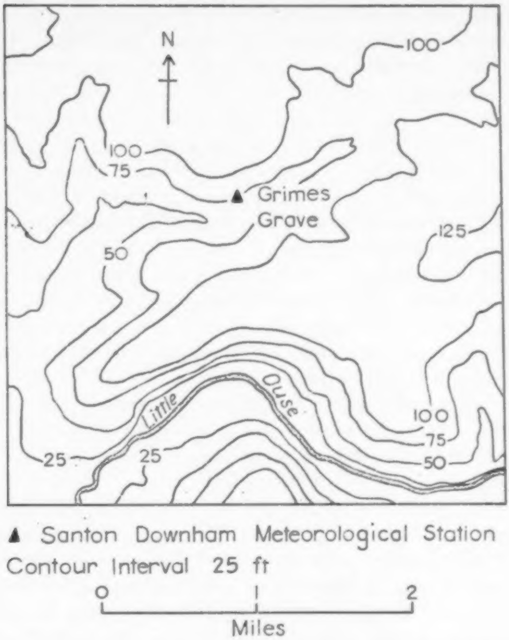


FIGURE I—MAP SHOWING THE TOPOGRAPHY OF THE AREA SURROUNDING SANTON DOWNHAM

Note: the spelling Grime's Graves is preferred.

occasionally be severe. Over the period 1958–64, Santon Downham recorded air frosts 12 times in June, 4 times in July and 4 times in August. The comparable totals for ground frosts (see note to Table III) were 37, 17 and 21. No other East Anglian station experienced air frosts in July, August or September during 1958–64. In July 1961 and again in July 1963, Santon Downham recorded an air frost and 5 days with a grass minimum temperature below 0·0°C, whilst in August 1964 there were two air frosts (one with a minimum of −1·7°C) and 6 days with grass minimum below 0·0°C.

TABLE III—AVERAGE ANNUAL NUMBER OF AIR FROSTS AND GROUND FROSTS AT EAST ANGLIAN STATIONS DURING 1958–64

Station	Number of frosts: air	Number of frosts: ground	Station	Number of frosts: air	Number of frosts: ground
Terrington St. Clement	60	91	Gorleston	33	55
Marham	63	88	Mildenhall	56	91
West Raynham	63	99	Lowestoft	55	64
Cromer	37	74	Cambridge Botanic Gardens	66	123
Sprowston	59	115	Santon Downham (see note (ii))	103	156
Burlingham	49	84			

Notes:—

(i) Ground frosts before 1961 were defined as days with grass minimum −0·9°C or below; for 1961 and after, days with grass minimum below 0·0°C have been used. For comparative purposes this does not raise any difficulty but the absolute figures are affected by the change of definition.

(ii) The minimum temperatures at Santon Downham are recorded at 0900 GMT. The total of air frosts at Santon Downham for 1958 has been estimated. No total for February 1958 was available.

The other information in Tables I and III illustrates in different ways the tendency for low night temperatures at Santon Downham. It is clear from Table III that local circumstances may make a station unrepresentative of the larger area in which it is situated. A station sited in a forest clearing under conditions of radiation cooling may well be affected by colder air draining from the canopy level, which would be the active heat-exchange surface, and accumulating in the clearing. Extremes of cold at night are thus more likely than in open sites outside the forest, and even lower temperatures could be expected in inversion hollows such as the floor of the Little Ouse valley nearby. The meteorological records at the Forestry Commission District Office at Santon Downham, nearer the river, do not show quite such a degree of night cold as Grime's Graves, although the extremes are more marked than at other meteorological stations in East Anglia. Sandy soils contribute further to such conditions. The poorer conductivity of sands with a coarser texture and lower moisture content, in contrast with heavier and wetter clays, would limit the upward transfer of heat to replenish surface losses. These factors would operate in a clearing, but under a tree cover soil qualities would become much less important. For instance, in the Thetford area on 4 July 1965, when a screen minimum of −0·5°C (at 4 feet) was recorded at Grime's Graves, readings taken over grass at a height of 6 inches in the centre of a large clearing on the same morning fell to −5·4°C. In five other clearings readings of −3°C or lower were recorded at 6 inches above the surface (information kindly supplied by Mr. J. M. B. Brown of the Forestry Commission Research Station). In addition to such local circumstances, there are other reasons for low night temperatures. The Breckland area, as a whole, is particularly liable to experience low night temperatures as other investigators have indicated (Day,[2] Manley,[3] and Hawke[4]). Distance from the sea and exposure to cold easterly winds play a part. The extreme minimum of −9·4°C for May in Britain occurred near Thetford, close to Santon Downham on 4 May 1941 (Manley[5]). This temperature was equalled at Fort Augustus on 15 May 1951. Cambridge and other stations in East Anglia have, on average, a high total of ground and air frosts (see Table III) but Santon Downham stands out clearly from amongst these.

Local climates are usually looked upon as aberrations from the normal climate of an area and, on occasions, there is an inclination to exclude or discount the local features as abnormalities or oddities when assessing the climatic environment. When the climatic relationships of agriculture (especially horticulture), forestry or even studies of human health are under consideration, full attention should be paid to the varying characteristics of different localities. Information on frost risk in the forest area of the Breckland is clearly of great importance especially from the viewpoint of establishing frost-sensitive species, and the Forestry Commission have an investigation in progress on frost incidence. At Santon Downham, for instance, the average annual number of days with a grass minimum temperature below 0·0°C over the period 1961–64 has been 175. If one is trying to select a 'representative' station considerable care is needed, as other unusual sites have shown, for example the frost hollow at Rickmansworth in the Chilterns (Hawke [4, 6]). For many practical purposes, however, actual rather than representative conditions are what matter.

To face page 16

Photograph by N. R. Watson

PLATE I — UNUSUAL ICICLES

This photograph was taken in early March 1965 at the Meteorological Research Flight, Farnborough. The most probable explanation seems to be as follows : The icicles originally formed vertically as heat from the interior of the building gradually melted a portion of the snow cap on the window-sill. The melting was greatest near the metal window frame and least near the edge of the ledge. The snow cap on the ledge was frozen to the pendant icicle and the whole slowly pivoted about the edge of the window-sill.

Crown Copyright

PLATE II—AIR MARSHAL SIR CHRISTOPHER HARTLEY INTRODUCING MAJOR K. J. GROVES AND MRS. GROVES AT THE PRESENTATION OF THE L. G. GROVES MEMORIAL PRIZES AND AWARDS ON 8 NOVEMBER 1965

See p. 26.

Crown Copyright

PLATE III—MAJOR K. J. GROVES PRESENTING THE MEMORIAL PRIZE FOR METEOROLOGY TO MR. L. P. SMITH

See p. 26.

Crown Copyright

PLATE IV—MR. A. SANDLAND RECEIVING THE METEOROLOGICAL OBSERVER'S AWARD FROM MAJOR GROVES

See p. 27.

To face page 17

Crown Copyright

PLATE V—DR. B. J. MASON, DIRECTOR-GENERAL OF THE METEOROLOGICAL OFFICE, ADDRESSING A PRESS CONFERENCE HELD AT THE METEOROLOGICAL OFFICE BRACKNELL ON 2 NOVEMBER 1965

Left to right seated: Mr. V. R. Coles, Mr. T. N. S. Harrower, Mr. J. K. Bannon and Mr. N. Bradbury (Assistant Directors) and Mr. E. Knighting (Deputy Director) (see p. 28).

Acknowledgements.—The data used in this discussion have been based upon the *Monthly Weather Report* and on unpublished information, for earlier periods, supplied by the Meteorological Office. Acknowledgement should be made also for details kindly supplied by the Santon Downham District Office and by Mr. J. M. B. Brown of the Forestry Commission.

REFERENCES

1. MANLEY, G.; The evolution of the climatic environment. Watson, J. W. and Sissons J. B. (editors); The British Isles - a systematic geography. Edinburgh, Thomas Nelson, 1964, p. 174.
2. DAY, W. R.; Local climate and the growth of trees with special reference to frost. *Q. Jl R. met. Soc., London*, **65**, 1939, p. 195.
3. MANLEY, G.; Topographical features and the climate of Britain: a review of some outstanding effects. *Geogrl J., London*, **103**, 1944, p. 241.
4. HAWKE, E. L.; Extreme diurnal ranges of air temperature in the British Isles. *Q. Jl R. met. Soc., London*, **59**, 1933, p. 261.
5. MANLEY, G.; Climate and the British scene. London, Collins, 1952, p. 257.
6. HAWKE, E. L.; Thermal characteristics of a Hertfordshire frost-hollow. *Q. Jl R. met. Soc., London*, **70**, 1944, p. 23.

551.558.21:629.13

SEVERE TURBULENCE AT LOW LEVELS OVER THE UNITED KINGDOM

By R. A. CASHMORE

Förchtgott's observations on turbulence in rotor-streaming at low levels made in rugged mountainous terrain in Central Europe are well known. There is an excellent summary in the WMO *Technical Note* on "The airflow over mountains"[1] which indicates that the requirements for rotor-streaming appear to be "high static stability and strong winds confined to a limited layer no more than about 1½ times the height of the hills". The text continues: "Förchtgott's work contains some well-documented cases of this particular variety of turbulence, but the sparsity of similar observations from elsewhere suggests that the phenomenon is rare, presumably because of the lack of suitable airstreams in other regions". Before Förchtgott's paper appeared in 1949, the phenomenon was unrecognized. By that time civil and military aircraft were flying, at any rate in the United Kingdom, at heights well above 1½ times the height of the hills; but, now that low-level flying by high-speed military aircraft and by light aircraft is increasing, severe turbulence in rotor-streaming may well become more frequently experienced than it has been in the past.

A period of severe turbulence in the lee of the Pennines lasting more than two days in an easterly régime has been described by Dent and Dyson[2], and an example of rotor-streaming at Acklington in a westerly airstream has been described by Gray and Stewart.[3] The object of this note is to present three more cases, two over Yorkshire to the lee of the Pennines and one over Scotland downwind of Ben Nevis; these cases are particularly interesting because the measurements recorded in the aircraft give some idea of the vertical gusts involved.

Case 1.—At 1450 GMT on 5 January 1965 a four-jet aircraft flying at 1500 feet above sea level, airspeed 250 kt, on a south-easterly heading, was passing over the Nidd valley over Pateley Bridge, about 11 miles north-west of Harrogate. A stratocumulus sheet, base 3000 feet, was continuous over the Pennines but broken over the Vale of York with a clear lane adjacent to the flight path of the aircraft. Approaching the Nidd valley the pilot observed a small dome-shaped cloud ahead, base 1500 feet, top 2000 feet, lateral dimension

about 2500 feet ; the top of the cloud was smooth, the base ragged. Just as the aircraft was entering this cloud, sudden violent short-period pitching oscillations were experienced, and the registered accelerations ranged from $-0{\cdot}75g$ to $+2{\cdot}1g$. The pilot climbed to clear the turbulence which continued in some degree until the level of the stratocumulus top was reached at 4500 feet. Aughton, the nearest radiosonde station upwind, reported winds from 290° at 1200 GMT, the wind thus being roughly at right angles to the ridge, and a marked inversion at about 880 mb, in good agreement with the observed position of the stratocumulus top. The maximum vertical acceleration produced an effect on this aircraft equivalent to vertical sharp-edged gusts of 37 ft/s upwards and over 60 ft/s downwards in rapid succession.[4] (The meter in undisturbed level flight records $+1g$).

Case 2.—At 1530 GMT on 26 February 1965 a similar aircraft at 1000 feet above sea level on an easterly heading was flying at 240 kt over Loch Leven, south of Ben Nevis, in relatively smooth conditions when sudden severe turbulence was experienced. The main upwind ridges all lie east-west. The Stornoway radiosonde ascent for 1200 GMT showed a stable layer at 800 mb and a northerly wind constant in direction with speed increasing with height. Vertical accelerations of between $0{\cdot}0$ and $+2{\cdot}0g$ were recorded.

Case 3.—This example also involved a similar aircraft flying to the lee of the Pennines but the inversion in this case was provided by an active warm front. The aircraft was at 2000 feet on route from Ouston to Lindholme, between 0001 and 0100 GMT on 18 June. The course lay parallel to and 100 n. miles ahead of the front. Continuous moderate to severe turbulence was experienced ; at one stage the pilot climbed to 6000 feet, but the turbulence did not decrease. The aircraft flew in and out of cloud, mostly between layers ; some turbulence existed all the time, but it was most severe at the cloud boundaries, as in Case 1. The Aughton radiosonde ascent for midnight was made 50 n. miles ahead of the front and a similar distance upwind of the aircraft track ; it showed an inversion at about 850 mb and wind speeds increasing with height. At Aughton the wind veered with height in the lower layers, but from this information alone it is difficult to say exactly what the wind direction was over east Yorkshire. Recorded vertical accelerations ranged between $0{\cdot}0$ and $+2{\cdot}0g$.

Summary.—This note suggests that severe low-level turbulence may be more common than the published literature has hitherto established. It also indicates the nature and magnitude of the effect. Turbulence of this severity under a warm front at low level[5] does not appear to have been documented previously and although Wallington,[6] for example, mentions the possibility of lee waves ahead of a warm front, he makes no mention of the possibility of severe turbulence.

REFERENCES

1. ALAKA, M. A. ; The airflow over mountains. WMO Tech. Note No. 34. (WMO-No. 98, TP. 43), Geneva, World Meteorological Organization, 1960.
2. DENT, L. and DYSON, B. ; Rotor streaming over the Pennines. *Met. Mag., London*, **92**, 1963, p. 358.
3. GRAY, A. and STEWART, W. J. ; Orographic effects at Acklington. *Met. Mag., London*, **94**, 1965, p. 8.
4. PARKER, A. E. ; Some effects of gusts on aircraft. *Met. Mag., London*, **88**, 1959, p. 225.
5. AANENSEN, C. J. M. ; Turbulence in clear air near a warm-front surface. *Met. Mag., London*, **77**, 1948, p. 209.
6. WALLINGTON, C. E. ; Meteorology for glider pilots. London, John Murray, 1961, p. 217.

551.501.81:551.507.352:551.515.4

METEOROLOGICAL OFFICE PARTICIPATION IN SEVERE STORM INVESTIGATIONS IN THE U.S.A. IN 1965

By T. W. HARROLD

During May and June 1965, a team of 29 persons (and also the writer) from the Royal Aircraft Establishments at Bedford and Farnborough was detached to the National Severe Storms Laboratory (NSSL), Norman, Oklahoma, to collaborate with the United States Weather Bureau in the investigation of the severe thunderstorms that occur in the area. The main objectives of the United Kingdom team were to obtain data on the operational and handling problems involved in flying aircraft through and near severe storms, and to obtain measurements of gusts. An additional aim was to attempt to use the data obtained to derive a model (or models) of the airflow in and around the storms and in connexion with this it was decided that a meteorologist should accompany the team.

Oklahoma was chosen as the location of the project because of the high probability of severe thunderstorms in the State during spring, and because of the excellent ground radar facilities at the NSSL. Radar is an essential tool in any investigation of the storms since it provides detailed information on their structure, and it can be used to guide aircraft to suitable locations. During past seasons the Weather Bureau has acquired considerable experience in using weather reconnaissance aircraft, in conjunction with radar, to investigate the structure and physical processes associated with thunderstorms, and this experience was of great value to the British team.

Three British aircraft were taken on the project. A Scimitar FI, a single-engine jet fighter, was used to fly through storms, usually at altitudes between 30,000 and 38,000 feet, depending on the height of the storm tops. It was equipped with instrumentation for measuring the vertical component of turbulence. During the 5 weeks the aircraft was in Oklahoma, 65 storm penetrations on 19 days were made. Generally the Scimitar worked in conjunction with an American F-100 aircraft, each penetrating a particular storm in turn. Two Canberras, a B 6 and a PR 9 flew around and over the storms. Both of these made gust and temperature measurements and were equipped with a Doppler navigator system which provided wind measurements. In addition, the PR 9 carried an airborne radar, while the B 6 had equipment for producing smoke trails, which gave an additional indicator of air motion. The Canberras flew at altitudes mostly between 40,000 and 45,000 feet.

At Norman, a WSR-57 radar, which has a 2-degree pencil beam and a wavelength of 10 cm, showed the location of storms to a range of 250 nautical miles on a Plan Position Indicator (PPI). A calibrated attenuator enabled the reflectivity to be measured, and the aerial was programmed to scan at a series of elevations, thus providing information of the three-dimensional structure of the storms. As well as a conventional PPI display there was a contoured display on which the reflectivity of a storm was shown as a series of light and dark contour bands. Dr. Lhermitte of the NSSL is also developing an *integrated* contour display which is an improvement on earlier displays in that it integrates a sufficient number of radar pulses to remove the fuzziness which normally occurs at the edges of echo because of the noise-like nature

of the signal. In addition to the WSR-57 radar, a MPS-4 4·7-cm radar provided range–height data on storms out to 80 n. miles. This radar was operated by the writer. Aircraft movements were observed on a PPI display from a 10-cm CPN-18 air traffic control radar at the laboratory. This radar provided a continuous record of the position of the aircraft relative to the storms to a range of 110 n. miles.

After a quiet period at the beginning of the detachment, thunderstorms, sometimes with hail and tornadoes, occurred on several days within 150 n. miles of Norman. These storms often developed into extensive squall lines, sometimes extending several hundred miles with cumulonimbus tops between 40,000 and 50,000 feet. Cloud tops over 60,000 feet have been observed in previous years but the highest during our detachment was 55,000 feet. On other occasions storms were more isolated but some of these were also severe, with strong winds, hail and tornadoes. One of the most interesting meteorological situations was on 27 May 1965, when two storms developed less than 20 n. miles apart. One of these, with a top around 40,000 feet, moved north-north-east at about 25 knots whilst the other, with a top over 50,000 feet, moved east-south-east at 20 knots. Three hours after their formation these storms were over 100 n. miles apart. A Canberra flying at 43,000 feet around the larger of these storms encountered a temperature change of 12 deg C in a little over 1 n. mile. The occurrence of storms close to Norman was rather disappointing, with only four storms passing overhead, three of these at night. However these were active storms by British standards, one of them producing about an inch of rain in 15 minutes and another wind gusts of 75 knots.

The writer found it exhilarating to participate in a project of this magnitude and to co-operate with people from a variety of disciplines. The first-hand experience of some of the effects of severe weather, both in the air and on the ground, was also very interesting. The detailed analysis of all the data acquired on this detachment will be a lengthy task but work is proceeding. It is a pleasure to record the excellent co-operation received from Dr. E. Kessler, Director of the NSSL and all of his staff.

551.509.313:551.511.3:061.3

INTERNATIONAL SYMPOSIUM ON DYNAMICS OF LARGE-SCALE PROCESSES IN THE ATMOSPHERE, MOSCOW, 23–30 JUNE 1965

The International Symposium on Dynamics of Large-Scale Processes in the Atmosphere held at the University, Moscow, from 23–30 June 1965, was jointly sponsored by the International Association of Meteorology and Atmospheric Physics and the World Meteorological Organization. Its purpose was to provide a forum for papers and discussion on the scientific aspects of global weather processes and to describe the most important problems that require solving before further progress can be made in large-scale weather forecasting.

There are three main types of problem. First, the problem of how to express the physical ideas in a simplified form in mathematical terms, then, that of actually solving the mathematical equations which have been evolved and finally the problem of obtaining the necessary data to enable one to use

the mathematical formulation. The first two problems are often treated together as a single problem because the people who formulate the equations are also the people who solve them. There is a danger here of the advantages of the most recent advances in mathematical techniques being lost owing to lack of communication between mathematicians and meteorologists. The mathematical techniques are usually the least discussed aspects of the problem and the papers that dealt specifically with methods of representing and integrating the equations were very welcome.

The papers dealing with actual integration of the equations of motion over short and long periods were a reminder that the solution of the problems of carrying out such computations is now at a more advanced stage than seemed possible only five years ago. There is now good qualitative agreement between the climatology of some of the models and the observed climatology, although in some cases it is perhaps difficult to be sure that the initial assumptions, sometimes expressed empirically, are not responsible for the good agreement. Almost everyone in the field would agree that there is still a very long way to go, but that progress so far has been most encouraging. It is perhaps worth noting that some of these computations are among the largest ever undertaken by man and make use of the most advanced giant computers.

The interest aroused by the discovery of the 26-month cycle has led to much research both on the tropical cycle itself and parallel cycles in extra-tropical zones. There were a number of fascinating papers concerned with this problem, dealing with the dynamics as well as relating the cycle to the circulation patterns in mid-latitudes, to the winter stratospheric warming, and so on. Perhaps the general opinion at the end of the conference was that the cause of the cycle remains as mysterious as when the cycle was first discovered.

Probably the greatest interest at the symposium was aroused by the problem of the data required in order to make longer-term predictions. It is well recognized that observations on a global scale are necessary, but are available in sufficient quantities only in the well-populated areas in the mid-latitudes of the northern hemisphere. The oceanic areas in each hemisphere are singularly lacking in data, despite the provision of weather ships. It seems that the traditional methods of making atmospheric observations are too expensive to allow a global coverage and that new and cheaper methods of obtaining the data are necessary. Such methods might include the use of buoys and constant-pressure balloons carrying instruments of new type and the use of satellites both to probe the atmosphere and to act as collectors and distributors of data. Experiments are about to be carried out, by both the U.S.A. and France, to establish the use of constant-pressure balloons and the next decade could well see a revolution in the methods of obtaining data and a vast increase in the amount available over the surface of the earth.

The symposium gave us the opportunity to discuss more easily with our Russian colleagues the problems that are of interest to all meteorologists. Our hosts were charming and provided all the facilities needed for a very successful meeting.

E. KNIGHTING

551.501.45:551.573:628.13

EVAPORATION FROM A RESERVOIR NEAR LONDON

By D. J. HOLLAND

Readers expecting reviews here to be of works by meteorologists might at first be surprised that this is a review of a paper* from an engineer in an engineers' publication. If so, however, they are perhaps also a little surprised — and perturbed — that the mean loss of water by evaporation from a reservoir near London is just about as large as the top-up received from the rainfall.

Not that this is news. It is not, in fact, the paper's main point. G. J. Symons, founder of the *Meteorological Magazine* and pioneer of the standard evaporation tank (*British Rainfall*[1]), had already collected, in *British Rainfall* 1869,[2] many studies of evaporation, one of which in particular — from C. Greaves, M.Inst.C.E., Engineer-in-Chief to the East London Water Works — actually indicated from a site near London a 10-year total evaporation amounting to more than 200 inches. And although the relevance of French data to London might be questioned at first, there undoubtedly was some relevance in an adjoining résumé (*British Rainfall* 1869,[2] p. 160) of data culled many years earlier from Dijon, and obtained with the aid of 8-foot square water-filled zinc-lined tanks which would seem to have been forerunners of the 6-foot square tank introduced by Symons. The Dijon annual mean evaporation for 1846–52 was apparently 26·1 inches, almost exactly balancing the 26·9-inch rainfall, and it is worth remarking that an annual mean evaporation of 26·1 inches is the very figure for 1956–62 now published in Mr. Lapworth's paper for the reservoir near London ; 24 inches had meanwhile been registered by a tank of Symons' pattern while the rainfall was 25 inches. Nearly a century later, in a well-known paper,[3] Penman estimated what he described as the hypothetical open-water evaporation, remarking that it might be of direct use in estimating losses from reservoirs. The annual totals of his estimates for stations in southern England all lay between about 23 and 30 inches. The value computed by him from data of Kew Observatory, in particular, namely about 28 inches, proved to be highly pertinent to Mr. Lapworth's work, not only because the reservoir under discussion was not far from Kew, but also because Dr. Penman himself, serving on the Evaporation Subcommittee which had been convened by the Hydrological Research Group of the Institution of Water Engineers for the express purpose of investigating the evaporation of this particular reservoir, proceeded to work out a fresh estimate based on data for the relevant period 1956–62. The final table of the Appendix to Mr. Lapworth's paper is actually a worked example of the present-day scheme of 'Penman' evaporation computation, from the hand of Dr. Penman himself. Worked examples which are as authoritative as this are seldom seen in print, and this one therefore has notable scarcity value.

What was special about the body of water under discussion, rendering it unique for the purpose in hand, and possibly raising the investigation into the ranks of the classics, was simply that no piped water passed in or out

---

Evaporation from a reservoir near London*, by C. F. Lapworth. $8\frac{1}{2}$ in × $5\frac{1}{2}$ in, pp. 18, *illus.*, reprinted from *J. Instn wat. Engr, London*, **19, No. 2, 1965, Institution of Water Engineers, 11 Pall Mall, London SW 1. Price : 5*s*.

at any time in a long term of years, the reservoir being nearly full but entirely untapped. Water level was thus governed solely—or almost solely—by rainfall and evaporation, on much the same principle as in the Symons type of tank and in well-known variants on the same basic scheme of gauging (e.g. the 'Class A' pan). The adventitious evenness of the natural balancing of those two factors in that particular locality duly kept the reservoir nearly full all the time ; and by recording the day-to-day fluctuations of water level along with the day-to-day rainfalls it was possible to get a long series of what were effectively direct measurements of daily, monthly and yearly evaporation from more than 40 acres of open water, and to test the tank and pan and other methods against them.

A test combining such size with such directness had never been achieved in this country before. Direct checks of the Penman type of estimate of open-water evaporation had hitherto been almost unobtainable, too, as Penman had said in his 1950 paper.[3] Admittedly wide acceptance had already been gained by Penman's method as applied to potential evaporation of vegetated ground, provided that nobody rated its accuracy very high. And although some high hopes were pinned on the 'Class A' pans that were going to be tried in Britain there had of course been generations of users of standard evaporation tanks, who, even if lacking an absolute accuracy test, had probably been quite happy to note the unfailing station-to-station coherence displayed by their data in the long run.

But the tanks had long been the subject of misgivings in certain quarters. Symons' original one, though seemingly keeping in quite good shape, had always read curiously low for London (it was at Camden Square until 1955) ; the much newer one at Kew read higher, and other fairly new ones in various places behaved like Kew's. A tank like Kew's was sited, at Kempton, alongside the reservoir, together with such rain-gauges and other instruments as were favoured by the Subcommittee in general and by the Meteorological Office and Metropolitan Water Board (MWB) members of it in particular ; and a programme of regular measurements was duly carried out — largely by the local MWB staff — from 1955 onwards. A 'Class A' pan, too, was installed when available, somewhat as was done at Kew Observatory at the time of the International Geophysical Year. The reservoir evaporation measurements ceased early in 1963 when everything froze ; but the pan and tank and rain-gauge readings went on afterwards and are going on still. The Subcommittee's report, in the form of Mr. Lapworth's paper, covers the 7 complete years 1956–62. The project ran into some problems, the solving of which indirectly involved organizations as far afield as the National Institute of Oceanography. Then there slowly emerged fairly clear-cut results, and whilst the discussion of them in the report is largely confined to the observations at Kew and Kempton the present review takes the opportunity to link them with what has meanwhile been found elsewhere in Britain.

The Kempton reservoir's evaporation, in brief, has been well matched by Penman's estimate when a physically rational allowance has been made for the deep water's albedo and heat-storage properties ; and it has been nearly — though not quite — matched (again after allowance for heat storage) by evaporation from Kempton's standard tank, which in turn has matched

Kew's almost perfectly on the average and has been in good accord with such tanks elsewhere as have been similar in all essentials *including freedom from major windbreaks.* (This last is now held to be a key requirement—key to why many of the older tanks read low.) All such tanks seem concordant, and moreover by a recent scheme of co-ordination of data from many sources in Britain, the Meteorological Office has indicated that every such tank has been registering what is approximately the potential evaporation of grass-land. (That this should be a little less than from deep water, of course, makes sense in terms of albedo, though admittedly the albedo of water-filled tanks is still a moot point). These tank findings have allayed former misgivings and have at least restored the tank technique to its original favour, if not indeed brought it into as high a favour as Penman's method, subject to the need to watch out for signs of over-shadowing of sites by windbreaks such as must have inhibited evaporation from Symons' tank at Camden Square.

Evaporation from Kempton's 'Class A' pan, on the average, was about 1·5 times its tank counterpart, or 1·4 times the evaporation of the reservoir. The scaling factor of 0·7 from pan to reservoir accords more or less with textbook ideas, and if other stations with pan-tank comparisons had had pan-tank evaporation ratios likewise averaging about 1·5 then all pan data would in effect have been parallelling the tank data. The 'Class A' type of pan — a United States Weather Bureau standard — had long had a reputation for being rather handier than the Symons invention, and so any such parallelling might well have permitted the pan to oust the tank as Britain's standard evaporation gauge. But in fact other stations have given ratios markedly different from 1·5, even after averaging over several years. Kew's figure, for instance, has been about 1·3. Each of several stations in Britain, having 'Class A' pan and adjacent standard tank exposed conventionally, has displayed its own characteristic pan-tank evaporation ratio, year after year ; but, although a station-to-station comparison has shown a lot of 'tank' coherence and some 'pan' coherence, it has shown striking incoherence among the ratios. Mr. Lapworth touches upon the Kew–Kempton disparity but does not dwell upon it, and readers in Britain might thereby have been lulled into too ready an acceptance of the idea of simply using a 'Class A' pan and multiplying the answer by about 0·7. Even the American recommended procedures for refining this rule, notwithstanding their textbook status, are clearly inadequate in Britain, and the whole technique has been falling from favour, at least in Meteorological Office circles.

Incidentally, readers of Mr. Lapworth's graphs of reservoir evaporation against "monthly evaporation using Tank" and against "monthly evaporation using Pan", will find that they have been left to think out for themselves, in the light of the paper's text, how to interpret the phrases "using Tank" and "using Pan". Scaling-factors and heat-storage terms have been quietly built into these graphs' construction, though the captions do not make this clear ; and anyone who is impressed by the overall matching of the estimates to the observations should bear in mind that the scaling factors were so designed as to achieve just this. The same can be said of yet another of the graphs, the one which shows reservoir evaporation against "monthly evaporation using Walker's method". Walker's method, by the way, a superficially attractive simplification of Penman's, emerges here from comparative

obscurity, virtually with Dr. Penman's blessing. Readers seeking to use it equally effectively elsewhere, however, should think twice. The simplifications which underlie it are to some extent just a happy accident.

The final item of Mr. Lapworth's own summary is salutary : "Values for individual months estimated by any of the four methods (tank, pan, Penman, and Walker) can vary from reservoir evaporation by as much as $\pm\frac{1}{2}$ inch".

REFERENCES

1. SYMONS, G. J. ; On evaporation. *Br. Rainf.* 1870, *London*, 1871, p. 177.
2. SYMONS, G. J. ; *British Rainfall*, 1869. London, 1870.
3. PENMAN, H. L. ; Evaporation over the British Isles. *Q. Jl R. met. Soc., London*, **76**, 1950, p. 375.

REVIEW

Die Tagebücher Franz de Paula Haslingers. Witterung und Klima von Linz: Anhang Band 1 1796–1817, *Anhang Band* 2 1818–1833, edited by Georg Wacha. $9\frac{1}{2}$ in × $7\frac{1}{2}$ in, pp. 259 and 212, Stadtmuseum, Linz, 1962 and 1964. Price : not available.

The first two sections of *Witterung und Klima von Linz*, a work published by the Stadtmuseum, Linz, in collaboration with the Zentralamt für Meteorologie und Geophysik, Vienna, were published in Linz in 1959. Section I by Georg Wacha, *Zur Wetterchronik des Linzer Raumes*, dealt in 80 pages with records from Linz and its surroundings from the Middle Ages down to about 1850, including tabular summaries of the daily observations of Haslinger from 1796 to 1833 now published *in extenso* in the volumes under review, which have also been worked up by Georg Wacha — Band 1 1796–1817, Band 2 1818–1833. Other interesting material in section I included brief daily weather notes from the observations of the astronomer Kepler at Linz from 1617 to 1626, tables giving daily values of temperature for the years 1760 and 1767 and a full list of the dry and wet spells of the period 1796–1833. Section II by Maria Roller, *Die 105-jährigen meteorologischen Beobachtungen in Linz von 1852 bis 1956*, also published in 1959, gave in 76 pages not only serial values of monthly mean temperatures, etc. for each year, but tables of overall averages and frequencies of almost every imaginable aspect of the local climate.

This work makes Linz, which lies on the Danube in Upper Austria, surely the city in all the world with the most accessible climatic history and about the most comprehensively summarized modern climatic data — just as Vienna, by another series of publications produced jointly by a city council and the Austrian weather service (*Klima und Bioklima von Wien*, Volumes I, II and III published in 1955, 1957 and 1959 respectively) can claim the most thoroughly investigated and documented study of local climates and microclimatic effects within a city.

Franz de Paula Haslinger (1765–1833), assistant priest in Hörsching on the south-west environs of Linz from 1789, pastor in Gallneukirchen a few miles north-east of Linz from 1797, and holder of various appointments at the Cathedral of Linz from 1806, was a devoted priest who recorded not only the weather (mostly with three temperature observations daily) but also visitations of the sick, etc. His 38-year record is the more effective as a

climatological document because he spent his working life within about 10 miles of Linz. His journals have survived *in toto*, apparently preserved till 1844 by relatives in the book trade, thereafter in the Oberösterreichische Landesarchiv at Linz. These volumes contain only the daily weather observations but at the end of Band 2 there is an 11-page glossary of the abbreviations used.

It may be doubted whether there is much of a market for such a complete reproduction in print of a weather diary of long ago. However, these two small volumes make a worth-while addition to the documented weather of the times before daily weather maps and should be available in the archives of meteorological institutions concerned with the functioning of our climate over the longest period for which it can be accurately known. Microfilm might have been more appropriate as the method of publication, to reduce bulk in storage, but these books produced by a lithographic process are better for the reader. The years contained happen to be of special interest being a harsh period of the Little Ice-age cold epoch, especially in north-west Europe, although possibly less marked in central Europe which escaped the rigours of 1816 and where the summers of 1826 and 1822 were notably hot, but still with many severe winters.

H. H. LAMB

AWARDS

L. G. Groves Memorial Prizes and Awards

The presentation of the L. G. Grove Memorial Prizes and Awards for 1965 was made by Major K. J. Groves in the Historic Room at the Ministry of Defence, Main Building, Whitehall on 8 November 1965. The presentation was presided over by Air Marshal Sir Christopher Hartley and attended by the Director-General of the Meteorological Office, Dr. B. J. Mason (see Plates II, III and IV).

The Memorial Prize for Aircraft Safety was awarded to Mr. M. J. Forrest of Loughborough, Leics., for designing an illuminated aid — simple, accurate, completely self-contained and easily portable in the field — to help visual landing by helicopters at night in difficult terrain. The equipment is adjustable to enable a helicopter to clear surrounding obstacles and land in a small open space which could previously only be used in daylight. Above all, it is virtually fool-proof, both to set up on the ground and for the pilot to follow. The 'Nightlight' approach and landing aid, to give it its correct name, is, says the citation, a "valuable contribution to aircraft safety".

The Memorial Prize for Meteorology was presented to Mr. L. P. Smith, B.A., a Senior Principal Scientific Officer at the Meteorological Office, Bracknell, for his work over 15 years as a pioneer in the investigation of meteorological factors affecting problems of agriculture, horticulture and forestry. The prize is given for the most important contribution to the science of meteorology or its application to aviation. Mr. Smith has discovered several relationships of practical value between meteorological parameters and animal and plant diseases or crop yields. The citation says : "He has also investigated the influence of climate on the distribution of grass and other crops, and devised techniques of forecasting milk production from weather observations. Recently

he has devoted attention to climatic change and its consequences for agriculture, which he has shown to be of considerable economic significance".

The Meteorological Observer's Award went to Mr. A. Sandland of Birmingham, for his work in Weather Ships over more than 12 years. When he returned to Britain recently in the *Weather Monitor* he had just made his 99th voyage. "His long experience and expert leadership", says his citation, "have proved invaluable in the training of new meteorological staff on Ocean Weather Ships, in their sometimes dangerous duties in rough weather. He helps them to accustom themselves to the unfamiliar conditions of life at sea, and encourages them to share his own pride in the tradition that the observing programme must be maintained in all weathers".

Chief Technician D. B. Parry of RAF Waddington, received the Second Memorial Award. He has designed a slim, light-weight back parachute pack which can be worn during flight, and does not impede exit, by navigators in B(I)8 Canberra aircraft. If they are above average size, navigators have hitherto experienced difficulty in leaving the aircraft in emergency because of the bulky chest parachute pack.

METEOROLOGICAL OFFICE NEWS

Forecasting for non-aviation purposes is increasing year by year, not only through the establishment of weather centres in large towns but also because outstations which were set up to meet aviation needs are dealing more and more with enquiries of a more general nature. A tribute to the work of one of these stations is the subject of the following letter which was sent to the Prime Minister.

NATIONAL FARMERS' UNION—LINCOLNSHIRE BRANCH
ISLE OF AXHOLME BRANCH

N.F.U. Office,
Temperance Hall,
Epworth,
Doncaster.
25th September, 1965.

Sir,

I feel I should like to draw your attention to the splendid work which the Meteorological Office at Bawtry has performed during the last season.

As representative of the farmers in this district who have, as you are no doubt aware, been faced with a long and difficult cereal harvest, I would like to pay tribute to the unfailing courtesy, technical knowledge, accuracy and — not least — the good humour of the officers who man this particular and important service.

I have personally utilised this "free" service as perhaps it has never been used before. I have rung them up at all hours. And, perhaps quite unknown to the officers who man this service, they have unwittingly saved us many thousands of pounds in the effective manner in which they have enabled us to deploy our labour to the best advantage.

The harvest, Sir, is nearly accomplished. And it would be quite easy for the Met. Service to be forgotten. Their usefulness is taken for granted. If I knew their superior officers I would write to them and express our gratitude.

But, I feel sure that you will do this for us, and let them know that the farming community owe them a debt of gratitude.

I am, Sir,
Yours faithfully,
R. B. KITSON
Branch Secretary

The Right Hon. Harold Wilson, P.C., M.P.,
10, Downing Street,
London, S.W.1.

Press Conference

The Director-General held a Press Conference at Bracknell on 2 November, 1965 to mark the introduction of routine numerical forecasts in the Meteorological Office. The Conference was attended by a wide cross-section of the national and technical Press, the BBC, and a large corps of photographers.

An introductory talk by the Director-General was followed by 45 minutes of lively questioning. The Press were then invited to watch the production of the first routine chart on the line printer, each correspondent receiving a souvenir copy. There followed visits to the Central Forecasting Office and informal discussions with senior members of the staff.

The Conference was reported on radio and television, produced leading articles in *The Times* and the *Financial Times* and was extensively reported in the national and local Press. The substance of the Director-General's talk is given below:

Ladies and gentlemen, it gives me great pleasure to welcome such a large and distinguished gathering of the Press to the Meteorological Office. Today is a landmark in the history of forecasting in the Office — a history which goes back more than a century — because this afternoon you will see the production of our first routine numerical weather forecast by the computer. But first I should like to introduce some of my colleagues (see Plate V) who are involved in this important project, and then take a few minutes to explain how the machine forecast is produced, its significance, its limitations, and something of our plans and hopes for the future.

As many of you will know, the traditional techniques of weather analysis and forecasting involve the preparation, at regular three- or six-hour intervals, of maps that give a two-dimensional representation of weather conditions at the earth's surface and at a number of levels in the upper air. Observations of pressure, temperature, humidity, wind and so on, made simultaneously at fixed hours at hundreds of stations all over the world are transmitted as quickly as possible to all countries on an internationally agreed basis. When these data are plotted on the maps the forecaster draws lines (for example isobars connecting places recording the same pressure and isotherms connecting places at the same temperature) which emerge as recognizable patterns that reveal the position, structure and evolution of weather systems. After careful study of these patterns in relation to similar charts for earlier times, the forecaster can extrapolate for some hours ahead the tracks of the main depressions and anticyclones and the movements of such features as troughs, ridges, fronts and rain areas. Here the forecaster relies upon a number of well-tested rules, his understanding of the physical processes, his experience of how similar situations have developed in the past, and his intuitive feeling for how the atmosphere works. This judicious combination of knowledge, experience, intuition, judgement and flair introduces a subjective element into the forecast. Nevertheless, even under the difficult conditions experienced in the British Isles, the main features of the daily forecast are correct on about 85 per cent of occasions ; not unnaturally the public tends to remember only the mistakes which, by the way, are usually errors of timing.

But over the years it has become apparent that the traditional techniques have been pushed nearly as far as seems profitable ; at any rate there is no

real hope of further major improvements. The objective is, of course, more comprehensive, detailed and accurate forecasts that will remain reliable for longer periods ahead. Among other things, this will require many more observational data from larger regions of the atmosphere. Now clearly there is a limit to the quantity of data that a human forecaster can assemble, assimilate, analyse and interpret in the short time allowed by the fact that he has to keep well ahead of the actual weather. This is where the big computers come to the rescue. They are able to handle huge quantities of data and perform vast numbers of mathematical calculations at very high speed. For example, our KDF9 computer, named COMET, can make an addition or subtraction in one millionth of a second. We have, of course, to tell it exactly what to do and how to do it.

I shall now try to explain, in simple terms, the procedure for making a numerical forecast. We work with a large section of the atmosphere stretching from Hawaii to Malaya, from the North Pole to central Africa, and extending up to a height of about 40,000 feet, and we concentrate on developments at three levels — at the surface, at 20,000 and at 40,000 feet. We subdivide this huge region by a grid, similar to lines of latitude and longitude, that provides 1300 regularly-spaced grid points. Fed with weather observations made simultaneously from 1200 land stations, 300 ships, and 600 radio-sounding balloons that transmit information on pressure, temperature, humidity and wind up to heights of 100,000 feet, the computer assigns a value for the pressure and temperature at each grid point at a convenient 'zero' hour. We also supply the computer with a very simplified mathematical description of the atmosphere — a set of differential equations to describe the gross behaviour of the air in our region and to allow the machine to compute how the pressure and temperature will change at each grid point during the next hour. (In practice it is more convenient to work in terms of two parameters called contour heights and thickness patterns, but these are closely related to pressure and temperature.) Using these new values the computer then carries the calculation forward in steps of one hour until, eventually, we have a forecast, for 12 or 24 hours ahead, of the distribution of pressure and temperature at the three levels. In addition, the machine calculates the large-scale vertical motions of the air which indicate regions of widespread cloud and rain and of dry settled weather. The whole operation takes less than one and a half hours.

Here I must emphasize that, because we are using only a very simplified model of the real atmosphere, the computer at present calculates only the gross features of the pressure and temperature field — the position and movement of the large weather systems such as the depressions and anti-cyclones. It does not attempt to deal with the detailed weather such as the occurrence of showers, thunderstorms and fog; these are added by conventional methods. Some progress along these lines is possible, at least in principle, but you will appreciate the magnitude of the problem when I tell you that one of our current research investigations on the development of a simple pair of fronts taxes the largest computer available in this country.

We show here a series of computed charts forecasting the conditions at midnight tonight ; for comparison we also show the corresponding charts drawn by the human forecaster. I think that you will agree that, as far as

the positions and magnitudes of the main pressure centres are concerned, the correspondence is very good. Such agreement is fairly typical in that, during the research trials, the computed forecasts of surface conditions were, on average, about as good as those produced by an experienced forecaster, while the computed upper air charts were consistently a little better. This degree of reliability in the numerical prognosis of the large-scale pressure field, essential to the production of a good weather forecast, is most encouraging. So, from today, the computed charts will serve as an additional aid to the forecaster. For a time he will continue to draw his conventional maps and use the machine forecast as a strong second opinion, but we hope and expect that, within a few months, he will acquire sufficient confidence in the computed charts to accept them unchanged. Since the machine actually prints the predicted values of pressure and temperature at each of the grid points on the chart, and will shortly be drawing the isopleths automatically, the forecaster may look forward to being relieved of much donkey work and to having more time for analysis and interpretation of his data and for presentation of his forecast to the customer.

Looking into the future, to more accurate forecasts for three, four or more days ahead, we shall need a number of things : a deeper understanding of how the atmosphere works on a global scale ; a more sophisticated mathematical description of the atmosphere ; many more observational data, particularly from the oceans and tropical regions and, perhaps, from the southern hemisphere; faster methods of communication to transmit these data; and bigger and faster computers. Given all of these and satellites too, we may look forward to gradual rather than dramatic improvements in the quality and range of the weather forecast. The atmosphere is an infinitely complex, subtle machine that will tax not only the largest computers, but more important, the best of our physicists and mathematicians for many years to come. Therein lies the challenge.

Dr. K. H. Stewart — special merit promotion to Senior Principal Scientific Officer

Dr. K. H. Stewart joined the Meteorological Office in 1949 following four years postgraduate research at Cambridge Univeristy on ferromagnetism. Apart from the usual training in synoptic meteorology, Dr. Stewart's career in the Meteorological Office has been devoted entirely to research in the physics of the atmosphere. From 1951 to 1960 his main interest was in the physics of fog and poor visibility. This work was pursued first at Headquarters and later at Kew Observatory where Dr. Stewart was promoted to become Superintendent in 1957. Dr. Stewart's interpretation and analysis of the special observations of fog made at Cardington under his guidance has done much to bring out the complexities of the physical processes of fog formation and point the way to a more realistic understanding.

In 1960 Dr. Stewart was transferred to the newly-formed branch for the study of the high atmosphere, and he has been largely responsible for the design and execution of novel experiments made from the Anglo-U.S. satellite Ariel II and from the rockets fired at Woomera. For such experiments new instruments have to be designed to make observations of quantities previously

unmeasured, under conditions far removed from laboratory experience. Their success calls for deep physical insight into the behaviour of both instruments and atmosphere. It is particularly appropriate that Dr. Stewart's achievements in this field should be acknowledged by his promotion to Senior Principal Scientific Officer under the scheme for the promotion of officers of special merit.

J.S.S.

NOTES AND NEWS

New Zealand Meteorological Service

Dr. J. F. Gabites succeeded Dr. R. G. Simmers as Director, New Zealand Meteorological Service on 15 October 1965.

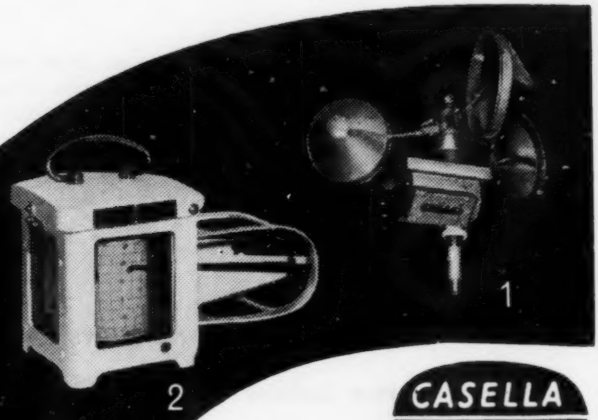
International Antarctic Meteorological Research Centre

The following is an extract from a letter received by the Royal Society from the Secretary of the Scientific Committee for Antarctic Research (SCAR) of the International Council of Scientific Unions :

> The Director of Meteorology in Australia has asked me to inform you that the International Antarctic Analysis Centre (IAAC) will in future be known as the International Antarctic Meteorological Research Centre (IAMRC). The change of title reflects a change in the type of work to be undertaken. Due to the establishment in Melbourne of a World Centre of the World Weather Watch, the IAAC has been relieved of the work of routine data and chart analysis, and the newly-oriented Centre is now free to concentrate on research related to Antarctic meteorology.
>
> Under the new arrangements, research meteorologists will be free to pursue the lines of their individual interest, but it is emphasized that facilities will be available for overseas meteorologists attached to IAMRC to work in the Southern Hemisphere Analysis Centre if they wish to develop and extend their synoptic analysis experience. Mr. H. R. Phillpot, formerly leader of the IAAC, will be in charge of the new Centre. A full account of these developments and the present structure of IAMRC will be published in the January issue of SCAR Bulletin.

Meteorological Service of Portugal
Retirement of Professor H. Amorim Ferreira

We have been informed that Professor H. Amorim Ferreira, former Director of the Meteorological Service of Portugal, retired from his post on 22 October 1965. Mr. José B. Blanc de Portugal will be responsible for the directorship until Professor Ferreira's successor is appointed.



CASELLA
LONDON

METEOROLOGICAL INSTRUMENTS

Meteorological instruments by Casella are specified by synoptic and climatological stations, by Universities, Geographical Societies and Government departments throughout the world.

1 **Cup Anemometer** Sloping Window for easy reading

2 **Thermograph** Robust, long life instrument

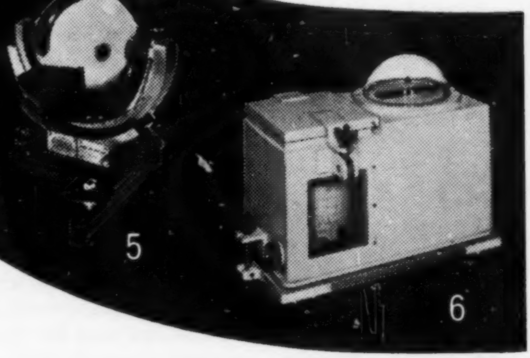
3 **Meteorological Screen** Available with Maximum Minimum and Wet- and dry-bulb thermometers

4 **Rainfall Recorder** Natural siphon, Tilting siphon, Rate of Rainfall and Long Period Recorder

5 **Campbell-Stokes Sunshine Recorder** Now used as the WMO Interim Reference Recorder

6 **Bimetallic Actinograph** Records short wave radiation from sun and sky Fully compensated for temperature changes

Send for Catalogue *MM877*



C. F. CASELLA & CO. LTD., REGENT HOUSE, BRITANNIA WALK, LONDON N.1

Telephone Clerkenwell 8581 - Telex 26 16 41

WHITELEY | MANSFIELD ENGLAND

Manufacturers of the

RADIO SONDE

METEOROLOGICAL TRANSMITTER

Supplied to the
British Meteorological Office
and many foreign governments

The W.B. Radio Sonde can be supplied either complete with battery, aerial parachute, radar reflector and battery or the transmitter with met. elements can be supplied as a single unit.

WHITELEY ELECTRICAL RADIO COMPANY LTD.

MANSFIELD . NOTTS . ENGLAND

THE METEOROLOGICAL MAGAZINE

VOL. 95 NO. 1122 JANUARY 1966

CONTENTS

	Page
The forecasting of shower activity in airstreams from the north-west quarter over south-west England and South Wales in summertime. C. A. S. Lowndes	1
Low minimum temperatures at Santon Downham, Norfolk. J. Oliver	13
Severe turbulence at low levels over the United Kingdom. R. A. Cashmore	17
Meteorological Office participation in severe storm investigation in the U.S.A. in 1965. T. W. Harrold	19
International Symposium on Dynamics of large scale processes in the Atmosphere, Moscow, 23-30 June 1965. E. Knighting	20
Evaporation from a reservoir near London. D. J. Holland ...	22
Review	
Die Tagebücher Franz de Paula Haslingers. Witterung und Klima von Linz. Edited by G. Wacha. *H. H. Lamb*	25
Awards	
L. G. Groves Memorial Prizes and Awards	26
Meteorological Office News	
Press Conference	28
Special merit promotion to Senior Principal Scientific Officer	30
Notes and news.	
New Zealand Meteorological Service	31
International Antarctic Meteorological Research Centre ...	31
Retirement of Professor H. Amorim Ferreira	31

NOTICES

It is requested that all books for review and communications for the Editor be addressed to the Director-General Meteorological Office, London Road, Bracknell, Berkshire, and marked "for Meteorological Magazine."

The responsibility for facts and opinions expressed in the signed articles and letters published in this magazine rests with their respective authors.

All inquiries relating to the insertion of advertisements in the Meteorological Magazine should be addressed to the Director of Publications, H.M. Stationery Office, Atlantic House, Holborn Viaduct, London E.C.1. (Telephone: CITy 9876, extn 6098).

The Government accepts no responsibility for any of the statements in the advertisements appearing in this publication, and the inclusion of any particular advertisement is no guarantee that the goods advertised therein have received official approval.

© *Crown Copyright* 1966

Printed in England by The Bourne Press Bournemouth, Hants.
and published by
Her Majesty's Stationery Office

Three shillings monthly **Annual subscription £2 1s. including postage**

Wt.24 K16 1/66 S.O. Code No. 40-43-66-1